STARS OF THE SOUTHERN SKIES

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SOUTHERN HEMISPHERE

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BY

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AND "DANTE AND THE EARLY ASTRONOMERS"

"All experience is an arch wherethrough
We glimpse the untravelled world whose margin fades
Forever and forever."

WITH ILLUSTRATIONS

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TO

MISS MARY PROCTOR

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LIST OF ILLUSTRATIONS

THE GREEK LETTERS

α	Alpha
β	Beta
γ	Gamma
δ	Delta
ϵ	Epsilon
ζ	Zeta
η	Eta
θ	Theta
ι	Iota
κ	Kappa
λ	Lambda
μ	Mu
ν	Nu
ξ	Xi
o	Omicron
π	Pi
ρ	Rho
σ	Sigma
τ	Tau
υ	Upsilon
ϕ	Phi
χ	Chi
ψ	Psi
ω	Omega

INTRODUCTION

This book is for those who have learned or are learning to recognise the southern constellations, but have not read much about astronomy, and have only an opera-glass or small telescope, or no instrument but their own eyes, for examining the stars. I assume that they have studied some simple guide to the constellations like Proctor's, or my *Southern Stars*, and that they would like to know something more about the stars they are looking at—how far off they are, how large, if they remain always the same, and if there is any connection between the different parts of this immense universe of stars and nebulae.

I hope that the book will be useful to teachers and parents, helping them to answer some of the searching questions children put, and to teach some of the facts of astronomy in the most vivid and unforgettable way—viz. in connection with special stars and nebulae which are at the moment being admired. If an opera-glass or field-glass can be put into the children's hands, so that they themselves can see a faint white spot turn into a lovely cluster of stars, it will give them a share

in the thrill of discovery, and help them to understand what large telescopes can show.

A map of the southern hemisphere is here given for ready reference, but it would be well to possess a good atlas which gives the letters and numbers assigned to all bright stars and shows the positions of the brightest star-clusters and nebulae. Norton's *Star-Atlas and Telescopic Handbook* is an excellent one, small enough to be handy, yet complete as far as it goes, and up to date, clear, and convenient to use.[1]

My intention is to treat specially of stars and nebulae visible in southern countries, so I have confined myself almost entirely to those of the southern hemisphere, though of course many which are north of the celestial equator can be seen also. My readers will find that the southern hemisphere possesses the most beautiful part of the Milky Way, the two brightest stars in the sky, the finest coloured star-cluster and the largest globular cluster, the brightest double star, the nearest of the stars, and the brightest of the large gaseous nebulae. Let us add that the southern hemisphere has been less studied than the north, and therefore there is an even wider field for amateur workers.

[1] Published at 5*s*. by Gall & Inglis, Edinburgh and London.

Stars of the Southern Skies

I

THE CONSTELLATIONS OF THE SOUTH: MODERN GROUPS

When we speak of the southern constellations, everyone thinks of the Southern Cross, and every traveller coming south for the first time is eager to see it. Some are disappointed because it is small and irregular, but it is very brilliant, and lies in an extremely rich region of the Milky Way. Very beautiful, too, is the way in which it is seen rising on its side and gradually becoming upright as it reaches its greatest height above the horizon, then sloping again as it glides westward.

The Cross seems to have been first so named by the Spanish explorer Amerigo Vespucci, at the beginning of the sixteenth century, and it was also described in letters by the Florentine Andrea Corsali, who says it is so beautiful that

in his opinion no other constellation in the sky is worthy to be compared with it. Some think, however, that the stars had already been recognised as forming a Cross as early as the thirteenth century, because Dante in his *Purgatory* speaks of four stars which glorified the southern sky; but he does not say they were in the form of a cross, and he tells us that they had never been seen before by mortal man except by our first parents, whose original dwelling-place he sets in the southern hemisphere. This negatives the suggestion that some traveller had described them to him.

About the same time as the Cross, other groups were named by sailors and travellers in the part of the sky round about the south pole, for this region had been left a blank by the framers of the ancient constellations, doubtless because they lived too far north to see it. Some students of astronomy in the Middle Ages concluded that there really were no stars in this part, and Ristoro of Arezzo gravely argued that this proved the absence of any land further south than India and Ethiopia; for where there are no stars to pour down influences on the earth no animals can live, and therefore no vegetation

is needed for their food, and no land for it to grow on.

The new constellations were mostly named after strange birds and fishes seen by explorers in their southern voyages, and they were admitted to scientific astronomy by Bayer, who made a map of the skies in 1604. He also introduced the plan of naming each star in a constellation by a Greek letter, the brightest of each constellation usually being called Alpha, the next brightest Beta, and so on. One of these constellations is Grus, the Crane (originally called the Flamingo), and it is convenient to be familiar with it, because from it we may easily identify several others. The chief stars of Grus form a striking curve with a bright star close beside it. This bright star is Alpha Gruis, and the brightest in the curve is Beta. A line through Alpha and Beta leads in one direction to the brightest star of the Phoenix, in the other direction to the brightest of the Indian; a line through Alpha and the little naked-eye double Delta takes one to Pavo, the Peacock; a line through Gamma (at one end of the curve) and Alpha goes to the brightest star in the Toucan. And these are all the modern groups containing bright stars except

the Southern Triangle, near the Pointers to the Cross (see p. 6), and Columba, the Dove, not far from Sirius, each of which has one star brighter than third magnitude.[1] We may, however, also notice Alpha Hydri, the brightest star in the small Water-Snake, close to the bright star Achernar, and Alpha Doradūs, the brightest of the Sword-Fish, between Canopus and Achernar.

In the eighteenth century the French astronomer Lacaille, who did much excellent work in the southern hemisphere with a tiny telescope of only half an inch aperture, had the unhappy idea of filling up the spaces still left empty with scientific instruments. It is easy to make Birds of Paradise and Flying Fishes out of the stars, but such things as telescopes, easels, and sextants do not lend themselves to irregular groups, and they are very much out of place among the mythical beasts and heroes which we are accustomed to see on our star-maps. Fortunately the beginner need not learn to recognise these intruders, for there are no bright stars in them,

[1] Stars are classified by astronomers in "magnitudes," *i.e.* degrees of brightness, those of first magnitude being the brightest. Stars below sixth magnitude cannot be seen with the naked eye.

although there are many interesting objects for telescopic study. We need only note that Octans, the Octant, occupies the region in which the south pole is situated, which is quite bare of bright stars. The pole itself may be found by drawing a line from head to foot of the Cross and carrying it on about four times as far again; or if the Cross is invisible, the pole may be found near the middle of a line from Canopus to Alpha Pavonis.

II

THE CONSTELLATIONS OF THE SOUTH: ANCIENT GROUPS

Let us turn once more to the Southern Cross to find the ancient constellations. It is both ancient and modern itself, for its stars were known to the Greeks of Alexandria, but were included in the Centaur. The latter, like all those shown in the accompanying illustration, is of great antiquity, and probably of Babylonian origin. The two stars which we call the Pointers to the Cross are Alpha and Beta of the Centaur, and mark his forefeet. Another conspicuous pair, Delta and Gamma, are on his horse's body, while his man's shoulders are marked by many bright stars, and the head is formed by a little group. His arm stretches out through bright Eta to Kappa, which is very close to Beta Lupi. For the Centaur and Lupus form one large and very brilliant group, and were perhaps connected with the little constellation of Ara, the Altar, upon which the Centaur seems

The Old Constellation Figures of the Southern Hemisphere.

to have been imagined as offering the creature which we now know as the Wolf, though its older name was simply the Beast. Aratus, a Greek poet of about 300 B.C., to whom we owe the earliest description extant of the ancient constellations, says of the Centaur :

> "His right hand he ever seems to stretch
> Before the Altar's circle. The hand grasps
> Another creature, very firmly clutched,
> The Wild Beast,—so the men of old it named."

On the other side of the Cross is another splendid constellation, the Ship Argo, which covers a large space of the sky with many bright stars, among them Canopus, the brightest in the whole heavens except Sirius. For convenience this large constellation has been divided into four—the Keel, the Poop, the Mast, and the Sails.

Sirius is north of Canopus, in the constellation of the Great Dog—Orion's Dog, as it is often called, for Orion is a hunter with two dogs; but the Little Dog is in the northern hemisphere, and Orion himself has his head in the north and his feet in the south, his famous belt and sword lying just south of the equator. Thus he is visible all over the world, and only at the poles

would his feet or his head never rise above the horizon. Beneath his feet is the little Hare, as Aratus says :

> " And ceaselessly beneath Orion's feet
> The Hare is ever chased."

Four stars of the Hare (α, β, γ, δ), which form a small square, were called by the Arabs the "Throne of the Giant" (*i.e.* of Orion) ; or sometimes "those which quench the thirst of the camel," in allusion to the river of the Milky Way which flows close by. Orion is mentioned in the books of Job and Isaiah, and also by Hesiod and Homer.

Above the Centaur and the Ship Argo stretches the long straggling constellation of Hydra, the Water-Snake. Its head reaches beyond the equator into the northern hemisphere, but the beautiful red star Alphard is in our hemisphere. This Snake is oddly connected with a Crow and a Cup, which are somehow perched on its back. (I have seen a snake pursued by an Indian crow, which kept pecking at its tail until the snake found refuge in a stream.) Crater, the Cup, has no bright stars ; Corvus, the Crow, is an irregular little square which sailors call Spica's Spanker, a spanker being a sail of this shape, and two

stars of the four point to Spica, the bright star of the Virgin.

Virgo, the Virgin, is one of the constellations of the Zodiac, that zone of stars which marks the apparent pathway of sun, moon, and planets in the sky. All the twelve zodiacal constellations can be seen in both hemispheres, but those south of the equator, which are least well seen in northern countries, are of course the best seen in the south. These are the Scales, Scorpion, Archer, Sea-Goat, and Water-carrier, with a very small part of the Fishes, and the part of Virgo which contains her brightest star, Spica, the Ear-of-Corn held in her hand. The Romans called her the Goddess of Justice, but these constellations were invented long before Rome was a great power, and the ear of corn shows that she was rather a goddess of the fields. They added that the Scales were her balance wherein she weighed the deeds of men, but this constellation was of much later origin than the Virgin: its place was earlier held by the Claws of the Scorpion.[1] In some old books we find a com-

[1] Compare Aratus:

> "The Virgin and the Claws, the Scorpion,
> The Archer and the Goat."

promise between the two ideas, for a pair of tiny scales is hung on the great claws of Scorpio.

Scorpio is a magnificent constellation as seen in the south. In England it merely creeps along the southern horizon in the pale summer skies, but in southern countries its whole splendid length rises high and shines, from the bright stars in its head and the ruby Antares on its back to the sting in its tail, represented by two stars close together.

Close behind Scorpio is Sagittarius, the Archer, also a brilliant constellation, with his bow strung ready to shoot the Scorpion; he is a centaur, like the figure near the Southern Cross. He is followed by Capricornus, a very strange animal, for it has the head and horns of a goat and the tail of a fish. As a modern writer quaintly says:

> "A startling monster's hybrid form
> Your eyes will there assail;
> That sign so often dubbed the Goat,
> Yet with a fish's tail."

Capricorn has very few bright stars. There are two in his goat's head, of which the brightest, Alpha, is a beautiful naked-eye double, and there are two in his fish's tail. These three figures—a Scorpion, Centaur-archer, and Capricorn—are

carved on old Babylonian boundary-stones belonging to the second millennium B.C.

Following these is Aquarius, the Water-carrier, his shoulder marked by the star β, and his pot by four stars (α, γ, ζ, η), from which fall splashes

THE ARCHER

From a Babylonian Boundary Stone now in the British Museum.

and streams of faint stars, aptly representing the water which he is pouring out. He is a familiar figure to those who have lived in some countries of the East where water is all carried by hand.

This is a very watery part of the heavens, for the zodiacal pair of Fishes follows the Water-carrier (their only bright star in the northern

hemisphere), and there is also a solitary Fish, Piscis Australis, swimming in the water poured out; while a little further east is the great Sea-Monster, which belongs to the northern group of Perseus and Andromeda and her parents Cepheus and Cassiopeia. Only the head of Cetus, the Sea-Monster, is in the northern hemisphere, but that contains its brightest star. Between the dim Sea-Monster and the bright Orion flows the winding River Eridanus: it rises near Orion's foot, and now ends very far south in the bright star Achernar; but this star was not visible to Ptolemy when he drew up his star-catalogue in Alexandria, and the original Achernar, or Last-of-the-River, seems to have been what we now call Theta Eridani, which was much brighter some centuries ago than it is now. Al-Sufi, an Arab writer of the tenth century A.D., calls it a star of first magnitude.

To complete our survey of the constellations south of the equator we must add the tip of the Eagle's wing, the legs of the Unicorn, and part of Ophiuchus with the Serpent he is strangling as he treads the Scorpion under foot (a gallant hero, to contend with both these enemies at once).

It is worth noting that just as the three stars of Orion's belt mark the celestial equator in one part of the sky, so the three bright stars of the Eagle mark it in the opposite part (Altair, with β and γ on either side); but they are just north of it, and Orion's belt is just south. As it is often interesting to know where the ecliptic lies, we may point out that the following southern stars lie near it: Spica, α Librae, Antares, α and β Capricorni (and in the north the Pleiades, Aldebaran, Regulus). It is also convenient to remember the positions of a few constellations as a guide to right ascension. Thus, Achernar is in the Ist hour, Canopus and Sirius are in the VIth, the Cross and Corvus in the XIIth, and the Bow of Sagittarius is in the XVIIIth.[1]

There are more bright stars in the southern hemisphere than in the north, for a count of all those above fourth magnitude shows that there are 228 south of the equator against only

[1] Right ascension in the skies corresponds with longitude on earth, but is more often reckoned in time than in degrees. For instance, R.A. 1 hour 35 minutes, the right ascension of Achernar, means that this star will be on the meridian 1 hour 35 minutes later than the "first point of Aries"—that is, the point at which the equator cuts the ecliptic at the spring equinox, the fundamental point corresponding with Greenwich in earthly longitude.

164 north. But whereas the stars in the north are fairly evenly distributed, there is a more strongly marked tendency in the south to congregate on the Milky Way, so that, while the tract through Argo and the Cross to Scorpio and Sagittarius is extraordinarily rich, the part between Orion and Fomalhaut is comparatively dark and bare, and the regions round the south pole and north of Argo are also very barren of bright stars. Some regions, however, which look dull to the eye abound in marvels for the telescope and camera.

The brilliance and the complex structure of the Milky Way is undoubtedly what most strikes the northerner travelling south. In England we have a glimpse of it in Cygnus and Aquila, where this rich and bright part begins; but there is nothing to equal the brightness or the mingling of dark and light which we see in Argo and near the Cross, in Scorpio and in Sagittarius. When this part is about to rise, there is often a glow on the horizon as if it were dawn.

III

THE TEN BRIGHTEST STARS OF THE SOUTHERN HEMISPHERE

The brighter of the two Pointers to the Cross, Alpha Centauri, ranks very high among first-magnitude stars, though it is excelled in brightness by Sirius and Canopus; but its greatest claim to our interest is that among all the host of stars it is our nearest neighbour. Yet, should we decide to pay a visit and travel with the speed of light (11 million miles a minute), it would be four years and three months before we could reach our destination—so great are the spaces which separate our sun with his family of planets from the nearest of his brother suns.

Alpha Centauri is also interesting as a double star. The two components are nearly equal in brightness, and are seen as a brilliant yellow pair in quite a small telescope. It was one of the first doubles known, being discovered as such in 1689; and Herschel calls it a "superb double star, beyond all comparison the most striking

object of the kind in the heavens." The two stars he describes as "both of a high ruddy or orange colour, though that of the smaller is of a somewhat more sombre and brownish cast."

All stars are suns, but they vary so much in brightness and size and quality of light that it is as difficult to match two stars in the sky as two trees in a wood. Yet one of this pair is an almost exact counterpart of our sun. The pair is approaching us, and at the same time revolving one about the other in a period of about eighty years.

The other Pointer, Beta Centauri, is a star very different from our sun. It belongs to a type called "Orion stars" because so many are found in that constellation. Instead of shining with a yellow light, they are blue or bluish-white, and their glowing atmospheres contain quantities of helium, the gas which was only recently discovered on earth though it had been known for many years in the sun. Oxygen and nitrogen and some yet unknown elements are also present.

Alpha Crucis, the brightest star of the Cross, is also a blue Orion star, and the telescope shows it to be triple. There are two bright twin stars, and a fainter one which would be just visible to the naked eye if alone, but being over-

powered by the brilliance of the bright pair can only be seen in a large telescope. Quite a small telescope will separate the twins.

Achernar, the Last-of-the-River, is also an Orion star, 75 light-years distant from us—*i.e.* light takes 75 years to come from it to us. The sun if removed to a third of this distance would be barely visible to the naked eye.

Rigel, Orion's foot, is the brightest star of this class. Its intrinsic brilliancy and its size must be enormous, for its distance is certainly more than 360 light-years, and may be greatly more. And the distance is increasing at the rate of 39 miles a second. Rigel is also a double star, but its companion is very faint. In an 8-inch telescope the bright star looks white or pale lemon-yellow, contrasting beautifully with the little companion which is blue.

Spica, the Ear of Corn in the hand of the Virgin, is immeasurably distant from us, and its companion is invisible even in the most powerful telescopes. It was discovered by means of the spectroscope, for, when the light of the star is drawn out into a long rainbow-coloured ribbon crossed by dark lines, it is found that there are two ribbons, one bright, the other very faint,

and that the lines of these two spectra draw apart and then come together again once in every four days, showing that there are two stars close together and revolving round one another in this short time. The joint mass of the pair is two and a half times that of the sun.

Spica is one of the first stars whose invisible companion was discovered in this way, and it is also connected with another discovery, made nearly twenty centuries earlier by Hipparchus in the island of Rhodes. He was patiently plotting the positions of all the visible stars, when he found a slight discrepancy between the places given to Spica by himself and another Greek astronomer, who had observed about a hundred and fifty years earlier. Examining into this led him to discover that all stars change their apparent positions very slowly, completing a cycle of change in nearly 26,000 years, so that 240 centuries more must elapse before any astronomer sees Spica in exactly the same place as where Hipparchus saw her. It remained for modern astronomers to discover that the apparent change is due to a slow nodding motion of the Earth's axis.

Brightest of all stars in the whole sky is Sirius,

the Dog-Star. It was worshipped by the ancient Egyptians, and the day on which it rose just before the sun was counted as the first day of their year. The Arabs, when they learned the astronomy of more ancient nations, were forbidden to adopt their star-worship, hence the saying in the Koran, often quoted by Arab writers: "The Highest saith, He is lord of Sirius."

Sirius is moving rapidly through space, not uniformly but with an oscillating movement, and Bessel in 1844 "founded the astronomy of the invisible" by showing that these irregularities might be caused by a dark disturbing companion. Eight years later, Mr. Alvan Clark, wishing to test a large lens just made by his firm, turned it on Sirius, and lo! there was the satellite in the position required to explain the vagaries of Sirius. It is not therefore wholly dark, but it shines with so feeble a light that, if it were brought as near to us as our own sun, it would appear only one-hundredth as bright as he is, even though it is a somewhat more massive body. Sirius itself is only about two and a half times as massive as our sun, but immensely more brilliant. It is the typical star of the "Sirian" class, to which belong many of the

brightest stars in the heavens, white stars in whose spectra broad hydrogen lines form the most striking feature, indicating a very extensive atmosphere of glowing hydrogen. Bright Sirius and his dim companion revolve round their common centre of gravity in fifty years.

Fomalhaut, the mouth of the Fish, belongs to the Sirian type of stars, and is also very brilliant, giving out fourteen and a half times as much light as our sun. Its distance is 25 light-years.

Canopus, the rudder of the Ship Argo, must be a giant sun, for its distance is altogether beyond reach of measurement and it is steadily receding from us, yet it shines as the brightest star in the sky except Sirius.

In Southern India it is called Agastya, after a Brahmin rishi who led an early Aryan colony to the south, and before whom the Vindhya Mountains prostrated themselves as he passed.

Greek astronomers noticed that this star rose only just above the horizon of Rhodes, but 7½ degrees above it at Alexandria, from which Poseidonius calculated that the circumference of the whole earth, *i.e.* 360°, must be 240,000 stadia. This is equal to nearly 23,500 miles, a value surprisingly near the correct figure, considering how

difficult it must have been to measure the distance over the sea between Rhodes and Alexandria.

Antares, the brightest star in the Scorpion, was so named by the Greeks because it rivals the red planet Mars (Greek Ares) in colour. It is red because a dense atmosphere shuts out most of its blue rays. Like most red stars it is very distant, and its light takes 155 years to reach us. Nevertheless it shines 2000 times as brightly as our sun would do at the same distance, hence it must be of an enormous size. This immense red star is accompanied by a little green satellite, and there is also a very close companion which can never be seen, but is known to exist through the shifting of lines in the spectrum, like that of Spica.

What an amazing variety among these ten stars! Though the eye can only decide that all are much brighter than the average, and that they differ somewhat in colour among themselves, science tells us that they vary enormously in many ways. Half belong to the class of blue Orion stars, others to the white Sirian, yellow solar, red Antarian classes; more than half are known to be double or multiple, and among these we find twins, while others have faint com-

panions differing from themselves in colour. In one case the pair is widely separated, and revolves in a period of half a century, while another pair is so close that the circuit is performed in four days. Again, while one star is the same size as the sun, others are much greater, and their distances from us vary all the way from four light-years to spaces we are powerless to plumb.

IV

STARS OF DIFFERENT AGES

WHAT is the meaning of these different types of stars—the blue, the yellow, and the red ? and can a star change its colour and type ? Yes, we believe that all the blue stars, if they follow the normal course, will in countless ages become red, and though the life of the whole human race may perhaps not be long enough to witness a single instance, we feel confident that this process is going on. One walk through a forest is enough to teach us that a tree grows from seed to sapling, from maturity to decay, because we see trees around us in all these stages. So with the stars. Here the process of development is far more difficult to understand, and we are still ignorant concerning the birth and death of stars ; but it is clear that we see a series of stages which pass gradually into one another, and that the cause of a star's growing old is a gradual loss of heat by radiation. The blue Orion stars are the brightest and hottest of all

those about which we have spoken, and are generally thought to have reached the climax of a star's career. They are great globes of thin gas, much less dense than water, but glowing hot through and through. The outer layers naturally part with their heat first, and in cooling they absorb more and more light from the radiant centre. As the blue rays are always first and most powerfully affected, the blue tint is soon lost, and the colour slowly changes through white, yellow, and orange to deep red. At the same time changes take place which cause different gases to become most conspicuous in the star's spectrum at different stages.

But what are the early stages which precede the brilliance of an Orion star? Arguments have been brought forward to show that young stars also are comparatively cool, but even less dense than Orion stars, that as they grow denser and smaller through gravity, which causes all the particles of a star to condense towards its centre, they must at first grow gradually hotter and brighter until a certain point is reached, after which they will grow cooler and fainter again until they become quite cold and dark; and so there is a double progression, viz. from red

towards blue, and back again to red, some stars changing in one direction and some in the other.

On the other hand, the stage which immediately precedes the Orion type somewhat resembles a peculiar class of nebulae, so the upward progression of the Orion stars may have been from nebulae through this stage.

Let us see what these stages are.

At one end of the series we find stars like Gamma in the Sails of the Ship Argo. When its light is spread out by prisms into a coloured band it is a wonderful sight, for not only are there dark lines and dark flutings, but wide bright bands mingle with these and stand out against the fainter background. We are fortunate to possess γ Velorum in the southern hemisphere, for it is the only bright star of its class. The type is known as WOLF-RAYET STARS, from the name of their discoverer. Only a few are known, and because of their faintness not very much has been discovered about them, but it is remarkable that all of them lie near the middle line of the Milky Way.

The bright lines in their spectra and some other features of Wolf-Rayet stars point (as we have said) to a connection with gaseous nebulae,

and it is possible that they developed from nebulae not very long ago—as time is reckoned in astronomy. Though this past is doubtful, the future of these stars is clearly indicated: they are destined to become Orion stars, for in stars like τ Canis majoris we see an intermediate stage between the two types.

Orion Stars sometimes have bright lines in their spectra also, especially the very blue ones found near nebulae, but the most striking and characteristic feature is the series of dark helium lines, from which they are often called "helium stars." The three in Orion's belt are typical of this class; several first-magnitude stars belong to it, as we have seen, and it contains others which are very bright, such as β and δ Crucis, β Scorpii, α Lupi, α Pavonis, α Gruis, α Sagittarii. Spica is a distinctly blue Orion star; Rigel and γ Gruis have already lost the blue tint and are approaching the next stage.

For the Orion class passes by gradual transition into the Sirian Stars, which may be called "hydrogen stars," from the wide hazy lines of hydrogen which are the most conspicuous feature in their spectrum. They are also very hot and bright, though less so than the Orion stars.

Besides Sirius, a large number of bright southern stars belong to this class, among which we may mention Fomalhaut, γ Centauri, β Carinae, δ Velorum, and β Pavonis. Among stars visible to the naked eye this is by far the most numerous class, partly, no doubt, because they are intrinsically bright and therefore visible at distances where redder stars could not be seen. This cannot however be the whole explanation, or the Orion stars would be still more numerous instead of being comparatively rare.

The blue end of the spectrum begins to be darkened as a star reaches the stage of sun-like or Solar Stars, and although the hydrogen lines grow narrower and less intense, an immense number of fine lines cross the bright band and absorb much of the light. α Centauri, as we have seen, is a replica of the sun, and another star which almost exactly resembles it, in spectrum if not in mass, is β Hydri. ζ Gruis and one star of the naked-eye double in Grus, δ^1 Gruis, are also solar stars.

This class may be subdivided into three: the Sirian-solar, which is typified by Canopus, and also by η Crucis and α Hydri; the solar, closely resembling the sun; and the red-solar, which

tend towards the red stars. The temperatures apparently are lower and lower in these three divisions in the order given, and all solar stars are cooler than those of the preceding classes. Among these red-solar stars is the beautiful ϵ Carinae, the foot of the False Cross,[1] which is a rich reddish orange even to the naked eye, and more brilliantly coloured in a binocular. Others are α Toucani, α Trianguli australi, ϵ Crucis (the little fifth star of the Southern Cross), the two brightest stars of Indus (α and β), almost all the bright stars of the Phoenix (α, β, δ, ϵ), and ϵ Scorpii which is beautifully coloured. This class is also extremely numerous among naked-eye stars, although they cannot be so bright intrinsically as the whiter solar stars : the significance of the fact is not easy to understand.

The deep-red stage is reached in suns like Antares, whose spectrum shows not only lines like those in the sun but also a series of broad bands or flutings which absorb much of its light, and in photographs a great part of the violet end is wholly cut off. Were it not such an enormous size, this would be a very dim star. ANTARIAN

[1] The stars ϵ and ι Carinae, κ and δ Velorum, form a cross much like the Southern Cross, but less bright, and this is called the False Cross.

Stars are almost all very remote. They are often very faint, and many of them are unstable in their light, as if fluctuating towards extinction. β and δ^2 Gruis and γ Hydri are among them, and Mira, the wonderful variable star. Compare the ruddy γ in the Cross with pale δ to see the contrast between stars of this class and the Orion type. Because of the want of blue rays in the former it makes so little impression on a photographic plate compared with α, β, and δ, which are all Orion stars, that one can scarcely recognise the form of the Cross in a photograph.

The brightest of these red stars are in the northern hemisphere, viz. Betelgueux in the shoulder of Orion, and Aldebaran, the eye of the Bull: both are slightly brighter than Antares.

Nearly all the stars we know have a place in this series, though there are individual peculiarities, but there is one class which seems to lie outside it. Stars of this class are red and have spectra crossed by dark bands, but they are unlike the Antarian bands and resemble instead those seen in the spectra of comets and of candle-flames. They are due to carbon compounds, so these stars may be called Carbon Stars. Most of them are extremely remote, and all are so faint

that among the very brightest is U Hydrae, just visible to the naked eye a little east of Alphard. They are probably aged stars, but no links between them and the other types have yet been discovered to enable us to place them in the series.

Strange and interesting discoveries have been made by grouping large numbers of stars into their classes and comparing the average motions, distances, &c., of the groups. It is found that the redder stars are on an average moving more rapidly and in a more random fashion than blue and white stars. Thus, Wolf-Rayet and Orion stars have a low average speed, and both are very much more numerous in and near the Milky Way than elsewhere ; Sirian stars are travelling a good deal faster, show a marked tendency to congregate in two streams, and move chiefly parallel with the plane of the Milky Way ; solar stars, including our own sun, move more rapidly still and show less preference for the Galaxy and the two streams : Antarians have the most rapid motions of all, but these appear to be haphazard, and the stars are scattered all over the sky in every direction.

These facts are very unexpected and very difficult to explain. It looks as if the Milky Way

were the birthplace of the stars, and that as they develop they gradually scatter through space; but how are we to explain the fact that speed and direction of movement differ for different types? There seems to be no reason why a cooler star should move more quickly than a hotter one, and none of the theories yet advanced can be considered final.

V

SOME NEAR NEIGHBOURS

If it is remarked that Sirius is fifty millions of millions of miles away from us, it is not at once obvious that he is one of our very near neighbours; but this is equal to 8 light-years, not twice the distance of α Centauri, our next-door neighbour among the stars. Some faint stars in the south must also be counted as very close to us: such are a little star in Cetus, τ Ceti, only 10 light-years away; ϵ Indi, 11½; and two in the River Eridanus, ϵ and δ Eridani, 10½ and 18 respectively.

But the most interesting among these near neighbours of the south is a little yellow star in Pictor, too faint to be seen without a good binocular or a telescope, and bearing the very modern name of CZ $5^{h}.243$. This stands for Cordoba Zones 5.243 hours, and means that it was catalogued at Cordoba Observatory in South America and its position fixed in the fifth hour of Right Ascension. After this it was observed

by Mr. Innes at the Cape, and he was startled to find (like Hipparchus comparing his work with that of Timocharis) that its position no longer agreed with that found at Cordoba. "Can this be motion?" he asked, and found that the star had indeed a larger visible motion across the sky than any other, not even excepting the famous "runaway star" in Ursa Major. Apparent motion, however, depends upon distance as well as real speed, and when the distance of CZ $5^h.243$ had been calculated it was found that its real speed, amazing as it is, yet falls slightly short of that of the northern star. The rates are 163 and 174 miles per second.

A few other stars are known to move at speeds approaching 100 miles a second, and one was announced in December 1913 to have a velocity of 200 miles a second, but runaway stars are rare. They do not seem to show any preference for special parts of the sky or special stellar types, and it is impossible to say what causes them to rush with such headlong haste through space, or what is their goal. The average rate for a star is about 13 miles a second, but, as we have seen, it differs with different types, the

average speed increasing progressively from the blue to the red classes.

Another remarkable fact lately discovered is that the different types of stars are not indiscriminately scattered through space. Our own sun seems to be surrounded, to a distance of about 100 light-years, by suns more or less like himself, while the greater number of the red Antarian stars lie at a much greater distance from us. Most distant of all, considered as a class, are the bluest of the Orion stars; for though the distances of individuals vary greatly, the average distance of these stars from us is more than 500 light-years. Yet they are often very bright, so this is another proof of their great intrinsic brilliancy.

VI

DOUBLE AND MULTIPLE STARS

Among the brighter stars at least one in four is double, and I shall only mention a few which for different reasons are of special interest.

The brightest double in the sky has already been mentioned, α Centauri, and we have also described another southern pair scarcely less brilliant, α Crucis, Sirius with his very dim companion, Rigel and Antares with theirs of contrasting colours. Other fine southern doubles are :

β Piscis australis, a white star with reddish companion, visible in a 3-inch telescope.

δ Corvi, an unequal distant pair, pale yellow and bluish, easily separated in a 4½-inch telescope.

σ Scorpii (near Antares), white and blue.

32 Eridani, yellow and blue-green—" magnifici, superbi," according to Secchi.

β Capricorni (close to the splendid naked-eye double α Capricorni), orange-yellow and blue.

γ Crucis, orange-yellow, companion fifth magnitude, rather distant.

γ Leporis, companion crimson. There is also a third faint star, forming a triple group.

β Capricorni, like Antares, besides its visible companion, has a close invisible one, only known by the shifting of lines in the spectrum, and this is not an uncommon case. β Crucis consists similarly of two bright stars and a spectroscopic companion, and so also θ Eridani. κ Velorum and α Pavonis have spectroscopic companions only, one revolving in a period of $116\frac{1}{2}$ days, the other of only $11\frac{3}{4}$ days, and the period of μ^1 Scorpii is counted in hours!—34 hours 42 minutes. The brief periods of these spectroscopic binaries[1] are in striking contrast with those of many visual binaries, such as ζ Sagittarii with a period of 19 years and γ Centauri with 150 years; and this is what one would expect, since the stars must be comparatively far apart and their orbits ample for them to be visible separately. Sometimes the stars of a pair or of

[1] A "binary" is a system of two stars which are known to be comparatively close together and influencing one another's movements. A "double star" may be a binary, or the two stars may really be very far apart and have no connection, merely happening to lie one nearly behind the other.

a group are known to be moving together through space, though no movement of revolution round a common centre has yet been detected, probably because it is very slow.

It is an interesting fact that most of the spectroscopic binaries, which are such close and rapid pairs, are found among the blue and white stars, the numbers steadily decreasing as we pass through the yellow to the red stars.

A significant fact about visual binaries is that companions which differ much in colour invariably differ much in brightness also. This is probably to be explained by supposing that one was from the beginning much larger than the other, and that there is consequently a difference in the rapidity with which each runs through its life-changes. Where the two are alike in colour and spectrum, like the two solar stars of *α* Centauri and the two Orion stars of *α* Crucis, it is found that they are also nearly equal in mass, so they keep the same pace and grow old together.

Among multiple stars there are some very remarkable instances in Scorpio. *β* Scorpii is a pair of bright stars (easily separated with a 3-inch telescope) with a third fainter companion, and besides these, one of the bright components is a

spectroscopic pair, and the whole company is travelling together through space. The joint mass of the spectroscopic pair is twenty-one times as great as that of our sun, and they revolve about one another in seven days; but a very strange feature is that *some* lines in their joint spectrum, due to calcium gas, behave differently from the rest, and it is thought that these two revolving stars may be enveloped in a calcium cloud which travels with them.

ξ Scorpii is a telescopic double which has been watched throughout a complete revolution of ninety-six years. It was discovered by Sir William Herschel in 1782. Here also there is a third star, much fainter and more distant than the brighter companion, and all are travelling together through space.

ν Scorpii is one of the "double-doubles," of which a good many are known, where a star that looks single to the naked eye is seen as a pair with a telescope, and each of these becomes a pair with higher powers. It has been described as "perhaps the most beautiful quadruple in the heavens." Both pairs journey together through the skies.

σ Orionis, the fourth-magnitude star just

below Orion's belt, separates very easily into two unequal components. Herschel found each of these to be triple, and called it a "double-treble." Later it was found to be "double-quadruple," with more stars between the two groups.

In the same way the beautiful naked-eye double star α Capricorni is seen in good telescopes to consist of two groups of stars, one (α^1) triple, the other (α^2) quadruple.

If a group like this forms a connected system, the motions of the several stars must be highly complicated.

VII

THE ASTONISHING STAR, ETA ARGŪS

MIDWAY between the Southern Cross and the False Cross there is a nebula visible to the naked eye, and in it once shone a bright star. When Halley was observing in the southern hemisphere towards the end of the seventeenth century, he catalogued it as of fourth magnitude, but Lacaille and later astronomers marked it as second. Sir John Herschel first saw it in 1834, when he was at the Cape, and he says that it remained steady for three years, from 1834 to 1837. On the 16th of December 1837 he began his observations as usual by noting the brightest stars in the heavens and arranging them in order on a list, when to his astonishment he saw "a new candidate for distinction among the very brightest stars of first magnitude" in a part of the sky where he was quite sure no such brilliant object had been seen before. He consulted a map and satisfied himself that it was his "old friend Eta Argūs," but nearly three times as bright as usual. He

made careful comparisons with other bright stars then visible, and says that "Fomalhaut and Alpha Gruis were at the time not quite so high, and Alpha Crucis much lower, but all were fine and clear, and Eta Argūs would not bear to be lowered to their standard." It was a little brighter than Rigel, and the only stars which outshone it were Sirius and Canopus.

Still it grew brighter, for twelve days later it greatly surpassed Rigel and could only be compared with α Centauri. After this the light began to fade, and by April 1838 it was not much brighter than Aldebaran.

Herschel now returned to England, and therefore he did not see the still more startling changes of this wonderful star, but he has recorded what he heard from others. In March 1843 it became much brighter than Rigel or α Centauri, but its light wavered, and he says: "We have here an epoch of great interest, a temporary minimum, with a kind of trepidation or fluttering of light, followed, however, by another step in advance even yet more extraordinary." This was in the following month, April 1843, when Eta became almost equal to Sirius, the brightest of all stars. It was the highest point reached by this extra-

ordinary star, and two years later Maclear at the Cape wrote to the Astronomer-Royal in England: "When you see Sir John Herschel again, tell him that Eta Argūs has been for some time rather larger than Canopus, and seems again on the decline."

Sir John's concluding remarks seem to indicate something of pained surprise that a star could behave in so erratic and unaccountable a fashion: "A strange field of speculation is opened by this phenomenon. Here we have a star fitfully variable to an astonishing extent, and whose fluctuations extend over centuries. . . . What origin are we to ascribe to these sudden flashes and relapses? What conclusions are we to draw as to the comfort or habitability of a system depending for its supply of light and heat on so uncertain a source?"

Eta Argūs continued to fade, and for many years it has not been visible to the naked eye. When the present writer looked for it in April 1908 it was beyond the power of the binocular, although seventh-magnitude stars in the neighbourhood were clearly distinguished and identified. In a telescope it in no way stands out from the crowd of small stars scattered over the

nebula whose light it once almost blotted out by its brilliance. Reports now and then arise that Eta is brightening again, but it always turns out that some neighbour in the throng, a little brighter than the faded star, has been mistaken for it.

A few other cases are known in which a bright star has appeared where none had been seen before. It is said that it was the appearance of such a "new star" in Scorpio in the year 136 B.C. which led Hipparchus of Rhodes to draw up his famous star-catalogue. In A.D. 1572 "Tycho's star" blazed out in Cassiopeia, and in 1604 "Kepler's star" in Ophiuchus astonished everyone. The old chronicle says: "It was exactly like one of the stars, except that in the vividness of its lustre and the quickness of its sparkling it exceeded anything Kepler had ever seen before. It was every moment changing into some of the colours of the rainbow, as yellow, orange, purple, and red, though it was generally white when it was at some distance from the vapours of the horizon." This "new star" must have been even brighter than Eta Argūs,[1] for it outshone Jupiter, and was only

[1] Now often called Eta Carinae, since Argo has been subdivided (see p. 7).

surpassed by Venus. It remained visible for about a year and then vanished.

Since the skies have been more carefully watched by astronomers all over the world, and especially since they have been frequently photographed, quite a considerable number of new stars have been recorded, and about half a dozen have become visible to the naked eye. In the twenty-seven years between 1885 and 1912, twenty were recorded, and half of these were discovered by Mrs. Fleming of Harvard Observatory from the examination of photographs.

Astronomers are still asking, like Herschel, what is the origin of these mysterious objects? Are they literally new stars, or is it the last flare-up of a dying system, or are we witnessing some catastrophe which only overtakes a few suns among the universe of stars? A collision between two dark stars, or between a star and a nebula, is a supposition which naturally suggests itself, and some probability is lent to this supposition by the fact that nearly every new star has appeared in or near the Milky Way, where stars throng most thickly; but there are difficulties in the way of accepting this hypothesis. There is a strong likeness between all that have

been examined spectroscopically, and in the declining stage they become so distinctly nebular in type that we seem justified in saying that new stars change into small gaseous nebulae.

Does this mean that they are dying, or is it the first stage in the life-history of a star, immediately preceding the not altogether dissimilar Wolf-Rayet stage? We do not know enough yet about nebulae to answer this question.

VIII

MIRA, THE WONDERFUL STAR

THE head of Cetus, the Sea-Monster, is formed of three stars in a crooked line (α, γ, δ); and a little beyond them, as far from δ as that is from α, you may sometimes see another star, marked on the map by the name "Mira," which means "Wonderful." Watch it carefully, and if it is on the upward grade you will see it slowly brighten until it equals δ, then γ, and if you are lucky it may even approach α in brightness; and meanwhile it will pass from red to a clear orange-yellow; then it will wane once more and gradually be lost to view, though you can follow it much longer in even a small opera-glass, and you will notice that as it grows fainter the colour becomes deeper and deeper crimson.

Unlike η Argūs with its one brilliant phase in two centuries, Mira waxes and wanes once in every eleven months, although there is a capricious uncertainty in both the period and the brightness which makes her a most fascinating

object to observe. Sometimes the maximum brightness is several days earlier, sometimes later, than the average; sometimes she only equals δ, she has been seen to excel α; and no one can foretell exactly what and when her maximum will be.

Quite a number of other stars have been discovered which behave like Mira, and anyone who wishes to contribute something to astronomical research without having to buy large and expensive instruments, or to study difficult problems, cannot do better than observe some of these stars, carefully comparing them night after night with stars in the neighbourhood. Here is a list of a few southern "variable stars of long period," as they are called, all of which are easily visible at maximum brightness with a binocular, and some even without. A map should be made of the surrounding stars, and a list drawn up of those which are of the different magnitudes through which the variable passes. Every fine night the star should be compared with these, and recorded in a note-book as brighter than one, fainter than others, perhaps equal to another, and so on, several comparisons being made to check each other. When the

variable passes out of the range of the binocular, this should be noted. The British Astronomical Association, which has a branch in Australia, has a Variable-star Section, and anyone who becomes a member will receive ready help and advice, and may have the pleasure of feeling that he is doing useful work in astronomy.

Most long-period variables are red stars of the Antarian or of the carbon-star classes with banded spectra, but they differ from ordinary red stars by occasionally showing bright lines, which indicate an uprush of intensely hot hydrogen gas in their atmospheres. These bright lines always appear at times of maximum, and prove that the star periodically undergoes some physical change: but what is the nature and the cause of this change? It can scarcely be due to the near approach of a satellite, because of the irregularity in the time of maximum. There is a certain resemblance between the way in which the light waxes and wanes and the waxing and waning in the number of sunspots on the sun, and spectra of these Mira stars also somewhat resemble sunspot spectra: can it be that our sun is an incipient variable star with a period of about eleven years? It is true that

Some Southern Variable Stars of Long Period

Name.	Maximum Magnitude.	Minimum Magnitude.	Period.	Remarks.
			Days.	
Mira . . .	1.7	9.6	331½	Discovered in 1596. Large irregularities in period and max. brightness.
R Sculptoris	6.2	8.8	376½	A red "carbon star."
R Leporis .	6.1	9.7	436	Crimson. A "carbon star." Observed from 1852 to 1883, but very few observations published since, so new work would be valuable.
T Centauri .	6.5	8.0	90¼	Period unusually short for this class of variables.
R Centauri .	5.3	13.0	568	An Antarian star. Double max. and min. The secondary min. about mag. 8½.
R Scuti . .	4.8	7.8	?	Bright and faint minima, usually alternative. Period perhaps irregular.
S Sculptoris	5.8	11.8?	366	
R Horologii .	5.9	12.0	405	
L^2 Puppis .	3.4	6.2	140 or longer	
R Carinae .	4.5	10.0	309	Antarian stars. Spectra very similar to that of Mira.
S Carinae .	5.8	9.0	148	
R Hydrae .	4.0	9.8	425	
S Virginis .	5.6	12.3	379½	
R Aquarii .	6.2	11.0	387	

sunspots seem to be cooler rather than hotter regions on the sun, but a time of maximum spots is also a time of maximum activity; slightly more heat is actually radiating, the corona is brighter and larger, and the bright scarlet flames of hydrogen and calcium which we call prominences are larger and more abundant. Possibly it is a tremendous display of these on Mira which makes the hydrogen lines bright at maximum.

Against this suggestion we must set the fact that no stars have been found to link together the slow and slight change represented by the sunspot period with the rapid and violent change suffered by Mira variables. Their periods, though never less than three months, are never more than two years, and the light radiated by Mira at maximum sometimes amounts to five thousand times as much as at a faint minimum.

Nevertheless, the fact that these perplexing stars are a link in an unbroken chain of which our sun also forms part suggests that research on the sun, our nearest star, will some day help us to understand more about Mira and stars like Mira.

IX

ECLIPSING STARS

There is another type of variables quite distinct from the Mira stars. These run through smaller light-changes in much shorter periods, also they change abruptly with clockwork regularity, and the spectrum shows no bright lines at maximum, indicative of physical change.

The first known was Algol, the Ghoul or Demon Star in Perseus, and the brightest southern star of the Algol type is δ Librae. It shines steadily for a little more than two days as a fifth-magnitude star, then in a few hours drops suddenly to below sixth magnitude, becoming invisible to the naked eye, and as quickly recovers its usual brightness. The entire change takes place regularly in less than two and a half days.

A few bright Algol stars in the south are :

Southern Algol Variables

Name.	Maximum Magnitude.	Minimum Magnitude.	Period.	
			Days.	Hours.
RS Sagittarii	5.9	6.3	2	9
R Canis majoris . .	5.8	6.4	1	2
δ Librae	4.8	6.2	2	7
R Arae	6.8	7.9	4	9

Altogether nearly a hundred Algol stars are now known, and seventy-four of these lie in or near the Milky Way.

Unlike the mysterious Mira stars, the variation of Algol stars has been explained. The sudden drop in the light is a partial eclipse, caused by a dark or partly dark companion which for a time hides the bright star from us. When a source of light is coming towards us, the lines in its spectrum are shifted towards the violet, when going away they are shifted towards the red, exactly as the whistle of an engine becomes more shrill when approaching us, and falls to a lower pitch when going away. In this way it has been discovered that an Algol star is revolving round an invisible companion, for it alternately approaches and recedes, and these movements correspond with its light-changes. It is, in fact, a spectroscopic binary which happens to have an orbit whose plane lies just in our line of sight, so that at every revolution one star passes behind the other.

The speed of the star in its orbit can be accurately determined (by the amount of shift in the spectrum lines) in miles per second, even when we do not know its distance from us ; hence the size of its orbit can be calculated, since we know the period in which it is completed ; and, further,

the size of the orbit gives us the mass of the stars, for their movements depend upon the attraction they exercise over one another, and this is proportional to their mass ; and so we are able to picture the system, although the eclipsing star is never seen and the distance from us may never be known. Here is indeed a triumph of modern astronomy.

Very curious are the systems thus discovered. Algol stars are extraordinarily light for their size, their density being always less, and sometimes immensely less, than that of water, and the companions are usually extraordinarily close together. In some pairs they seem to be actually touching. Nearly all are Sirian stars ; a few are of Orion and solar types.

Sometimes the companion star gives light also, instead of being dark, and then we have a different type of variation. There are two eclipses in one revolution, each star passing alternately behind the other, but neither is a very dark eclipse, only a lessening of light. β Lyrae was the first star of this kind to be discovered ; its southern counterpart is U Scuti, which varies from magnitude 9.1 to 9.6, and runs through its two maxima and two minima in less than twenty-three hours ! It is a Sirian star.

X

SHORT-PERIOD VARIABLE STARS

ANOTHER extremely interesting class of variable stars runs through the periods as punctually as the Algol stars, but the light is varying up and down the whole time without any period of steadiness. The length, too, is often much greater, though not nearly so great as that of the Mira variables.

Here are a few stars of this class bright enough to be observed with a binocular, at least at maximum :

SOUTHERN SHORT-PERIOD VARIABLES

Name.	Maximum Magnitude.	Minimum Magnitude.	Period.
			Days.
W Sagittarii	4.3	5.1	$7\frac{1}{2}$
κ Pavonis	4.3	5.2	9
l Carinae	3.6	5.0	$35\frac{1}{2}$
S Crucis	6.5	7.6	$4\frac{1}{2}$
V Centaurii	6.4	7.8	$5\frac{1}{2}$
S Trianguli australi . .	6.4	7.4	$6\frac{1}{2}$
S Normae	6.6	7.6	$9\frac{3}{4}$

The three first on the list have been discovered to be spectroscopic binaries, the motions varying

with the light, and as this is found to be the case with all those whose motions are known, there can be little doubt that all variables of this class are binaries. Their orbits, however, are somewhat larger than those of the Algol variables, and are tilted towards us so that neither star can be seen to pass in front of the other. For the gradual and continual change of light cannot possibly be caused by an eclipse. Yet it seems clear that it is in some way connected with the revolution of two stars about one another.

Various suggestions have been made, such as that the revolving star is unequally bright over its surface, and shows us now its brighter and now its duller face; that the two pull one another out of shape when they approach most nearly; that they are permanently elliptical, and turn to us first the broad and then the narrow face. Any or all of these may play some part in the variations of the light. But the most hopeful theory takes into account a very strange fact lately established, viz. that the variable is at its brightest not when approaching its fellow but when coming directly toward us, and at its faintest when receding directly from us.

This theory is that a dark and a bright star are

involved in a kind of thin nebulous cloud, and that the bright revolving star has an enveloping atmosphere. As it moves through the cloud this atmosphere is continually brushed back from its advancing face, and therefore we shall see it when coming straight towards us through a less thickness of atmosphere, and it will look brighter than when it is retreating from us.

There are grave difficulties in accepting this view, but it receives some support from the case of β Scorpii, in which, as we saw, a double star is suspected, for quite a different reason, of being surrounded by a thin cloud. And the atmosphere supposed to be surrounding the bright star may resemble the "smoky veil" which we know envelops our own sun, and causes a considerable absorption of light, for these variables are solar stars. The resistance of the cloud to the motion of the revolving star ought in time to shorten its period, and some variables have been found to be shortening their periods.

Short-period variables are found chiefly in the Milky Way.

XI

IRREGULAR AND DOUBTFUL VARIABLES

Besides these well-marked classes of long-period, short-period, and Algol variables, there are some stars which seem to vary spasmodically, remaining sometimes for months or even for years without any change; and there are others whose variability is suspected but has never been confirmed. Useful work might be done by amateurs in trying to decide the status of these doubtful stars.

It must be borne in mind that red stars are notoriously difficult objects. Two observers comparing one at the same time with the same star will often come to opposite conclusions, showing how difficult it is to compare stars which differ much in colour. Whenever possible, red comparison stars should be selected to avoid this uncertainty.

The second star on the list below has a very peculiar type of variation, unlike any other

except a northern star, R Coronae, and a third recently discovered. The spectra of RY Sagittarii and R Coronae are also peculiar and resemble one another.

The following are bright southern variables suspected to vary, or known to vary without recognised laws:

SOUTHERN IRREGULAR AND SUSPECTED VARIABLES

Name.	Maximum Magnitude.	Minimum Magnitude.	Remarks.
Z Sculptoris	6	8	Period unknown.
RY Sagittarii	6.5	Fainter than 11.5	Usually steady, but subject to a sudden drop at irregular intervals. Worth watching.
RT Capricorni	6.5	About 8	Period probably irregular. Very few observations published.
S Phoenicis	7.2 or 6.8	8.7 or 8.4	Observers differ. Period irregular.
W Ceti	6.5	12	Period perhaps 366 days.
T Ceti	5.4	6.9	Irregular.
S Leporis	6.5	7.5	Irregular.
U Hydrae	4.5	6.3	Irregular. Red "carbon star."
θ Apodis	5.5	6.6	Period probably irregular.
R Apodis	5.5	6.2	Suspected.
T Indi	7.2	8.9	No regular period found.

XII

STAR-CLUSTERS

ENDLESSLY varied is the grouping of the stars. We find solitary stars, twin stars, large stars with small companions, bright stars with faint companions, stars alike in colour and type, stars in strongly contrasted colours, one young, the other aged, stars with invisible companions, couples close enough to touch one another, and couples so distant that the satellite takes more than a century to revolve round its primary. One or even both components of a bright pair may be themselves divisible into a closer pair, sometimes into a whole group of stars.

More beautiful and wonderful still are the clusters of stars of various tints and magnitudes, where scores, even hundreds, are gathered together in what to the eye is a tiny patch, though it may in fact take light many years to cross from one side of it to the other.

The finest example in the heavens of this kind of cluster is Kappa Crucis, near β in the Southern

Cross.[1] It is just visible to the naked eye as a small star, and in a binocular the main star is seen to be surrounded by a number of others; in a telescope it is a glorious sight. Orange and red stars are easily distinguished in the brilliant throng, even if we have not Herschel's eye for colour and fail to discriminate the "greenish-white, green, red, blue-green, and ruddy" which made up what he likened to "a superb piece of fancy jewellery." He charted over a hundred stars of all magnitudes from 7 to 17. Herschel's observations at the Cape were made between 1834 and 1838. When Mr. Russell charted the stars of Kappa Crucis at the Sydney Observatory in 1872, he found 25 that had not been recorded by Herschel, although the great reflector was much larger than the Sydney instrument; many of Herschel's stars had drifted, and five could not be found at all. If changes so striking as this take place in less than forty years, "it is evident," as Russell observed, "that more attention should be bestowed on clusters."

Quite a dozen star-clusters of this kind are

[1] It is easy to remember the names of the stars in the Southern Cross. Begin at the foot, which is obviously the brightest, and count round the Cross in clockwise direction α, β, γ, δ. κ is beyond β in a line with γ, β.

visible to the naked eye in the southern hemisphere, the most striking being in Scorpio, where it shines as a conspicuous silvery spot just beyond the Scorpion's tail, midway between κ Scorpii and γ Sagittarii. It is named M 7, which means the seventh in Messier's list of clusters and nebulae. In a binocular it is seen to be a group of very many stars, some close together, others scattered. Lacaille, with his little half-inch telescope, counted from 15 to 20 stars, and Herschel, with his large reflector, estimated the number at 60. At Cordoba Observatory no less than 139 were catalogued.

M 6, a little north and west of M 7, is also visible to the naked eye as a nebulous patch, and is a fine cluster. About 50 stars between magnitudes eight and twelve have been photographed, and there are doubtless many more of lesser brightness.

Look also just above the naked-eye double ζ in Scorpio, and see what appears to be a hazy star. A binocular separates this into a number of small stars, and 150 have been photographed, of magnitudes seven to twelve. It is known as h 3652 or N.G.C. 6231, the former being the number in Sir John Herschel's catalogue, the

latter in Dreyer's New General Catalogue of star-clusters and nebulae.

A little south of Sirius is a patch of nebulous light which shows as stars in a binocular. This was registered by Messier in 1764 as a "mass of small stars," and is known as M 41. Webb saw the brighter stars arranged in curves and a ruddy star near the centre. One hundred and forty-four stars were registered by Gould, of which only five are as bright as eighth magnitude.

In the neighbourhood of the Cross there are quite a number of large bright clusters, for they must be large and bright above the average to be seen by the naked eye. A line passing through the shorter arm of the False Cross—*i.e.* from δ Velorum to ι Carinae, the naked-eye double—and continued for an equal distance beyond, leads to a white oval patch which is plainly visible to the naked eye, and in the binocular appears like a few stars sparkling on a nebulous background. With higher powers the background also is resolved into stars, of which there are some two hundred of the fifteenth magnitude and brighter up to the eighth. This is N.G.C. 3114.

In the same direction is θ Carinae, a bright Orion-type star with numerous small stars

crowding close to it. This is a very lovely group in a good binocular. It contains about twenty stars of magnitudes between three and eight, and with high powers appears as a brilliant, loosely scattered cluster covering a portion of sky equal in breadth to twice the sun's apparent diameter.

Very similar is a cluster close to the bright and richly coloured star X Carinæ. It looks like an elliptical nebula in a binocular, with a few stars scattered over it. Two hundred have been photographed.

Near ε Carinae, the beautiful ruddy star at the foot of the False Cross, is yet another most beautiful cluster, which contains about fifty stars of the ninth magnitude and brighter. It is visible to the naked eye, but when a telescope is turned upon it the brilliancy is startling. Radiant stars are scattered all over the field.

Just east of π Puppis, the top of the poop of Argo, is a fourth-magnitude star C of a bright orange colour, and round it is a cluster which Gould describes as "extremely impressive to the naked eye." Ninety-two stars show on his photograph.

Close to δ Velorum (in the False Cross) is the

star *o* Velorum. Even to the naked eye the bright star ($3\frac{1}{2}$ mag.) is seen to be surrounded by a cluster of faint stars, and in a binocular it is a splendid sight. The number of stars is small, but they are bright, ten being above the ninth magnitude.

Lastly we may mention a remarkably fine cluster which is visible in a binocular though not to the naked eye, in the Centaur, among a stream of small stars between the Cross and η Argūs. Dunlop called it "a pretty large cluster of stars of mixt magnitudes"; Brisbane, "a prodigious number of small stars very close together."[1] There are at least a hundred above the sixteenth magnitude.

It should be noticed that nearly all these clusters are in the Milky Way, and the rest are very near it, for this is characteristic of star-clusters like these, viz. irregular groups containing mixed magnitudes of stars. In a list of all bright objects of this kind, only two are found as far as 30° away from the middle line of the Galaxy, while 89 are within 30° north or south of it. There are besides 38 in the Clouds of

[1] These two astronomers observed at Paramatta, New South Wales, in the early part of the nineteenth century.

Magellan, which resemble the Milky Way in constitution. Many clusters are simply unusually dense portions of the Milky Way, and we may almost say that this type forms part of it and of the Magellan Clouds.

XIII

GLOBULAR STAR-CLUSTERS

If Kappa Crucis is the finest irregular star-cluster in the sky, Omega Centauri is undoubtedly the largest and most splendid of all the globular star-clusters, for its diameter is more than twice the diameter of the famous northern cluster in Hercules. It is easily found, being nearly in line with δ and γ Centauri (the two conspicuous stars just north of the Cross) and a little further from γ than γ is from δ. The cluster looks to the naked eye just like a tailless comet, and was mistaken for one by the author when first seen. In a binocular it is quite round, the soft milky light growing gradually brighter towards the centre, but without the slightest suggestion of irregularity, and no appearance of stars. It must have been seen by the early navigators who named the southern constellations, but it was first discovered as a star-cluster by Halley in the island of St. Helena. Most amazing is its appearance in a telescope,

for the milky disc breaks up into thousands of tiny points of light, densely crowded, all alike, innumerable.

"This most glorious object," as Herschel calls it, "the noble globular cluster ω Centauri, beyond all comparison the richest and largest object of the kind in the heavens," is evidently quite distinct from κ Crucis and clusters like those described in the last chapter. In form it is circular, and the condensation towards the centre suggests that it is spherical. There are some scattered members of the group lying outside the bright crowded sphere. The stars are also immensely more numerous and more closely packed than in the irregular clusters, their total number being estimated at 10,000, and 6000 have been actually counted on photographs, and all these in a space which looks little larger than that occupied by the sun in the sky. Another striking difference is that, instead of bright and faint stars mingled together, here they are all nearly alike and very minute. Curiously enough, it is found that they belong to two magnitudes, and two only, the thirteenth and fifteenth, and this seems to be a feature of all globular clusters, as well as the form and the

dense crowding of the stars. Herschel at first thought the stars in ω Centauri "singularly equal, and distributed with the most exact equality, the condensation being that of a sphere equally filled." But he immediately adds: "Looking attentively, I retract what is said about the equal scattering and equal sizes of the stars. There are two sizes . . . without greater or less, and the larger stars form rings like lace-work on it." In his later notes he is again doubtful, for he thinks that the effect may be optical, and the larger stars only knots of faint stars; but photography has settled the question in our day.

Yet another point of difference between globular and irregular clusters is that the latter often have wisps of nebulosity clinging about them, but globular clusters are entirely free from it.

Smaller than ω Centauri, but even more beautiful in the telescope, is the cluster 47 Toucani,[1] which to the unaided eye appears like a fourth-magnitude star near the smaller Cloud of Magellan. The long curve of Grus followed southwards leads to it. Nearly as many stars as in ω Centauri, or about 9500, are here massed into

[1] Also named ξ Toucani.

THE STAR CLUSTER 47 TOUCANI
From Sir John Herschel's drawing

a still smaller space, so the cluster is brighter, and is "compressed to a blaze of light" at the centre. The two sets of stars, which are mingled together throughout, are of thirteenth to fifteenth and of seventeenth magnitudes respectively. Herschel saw the inner denser part rose-coloured while the outer was white, but the present writer could not see this nor find anyone to confirm it to-day, possibly because the refracting telescopes now so often used do not show colour so well as large reflectors like Herschel's. A double star of 11th magnitude, which is conspicuous in Herschel's drawing, is doubtless far outside the cluster, and only appears projected against it by perspective.

Near β Aquarii there shines with the light of a sixth-magnitude star another "magnificent ball of stars" which has been compared to "a heap of fine sand." It is named 2 M Aquarii.

Over seventy of these tightly packed balls of stars are known, even counting only the brightest, and their distribution is rather curious. A large number (about twenty) occur in the Clouds of Magellan, and more than half of the seventy are in the Milky Way, not scattered evenly along

its course, but almost if not entirely confined to its southern part, and chiefly gathered in a great group in its brightest portion, where it passes through Sagittarius, Ophiuchus, and Aquila. Here they are mingled with—or perhaps projected against—numerous stars of the same magnitudes; but many balls are also found outside the Milky Way, widely scattered, and in these parts of the sky there are relatively few of the faint-magnitude stars which compose all the globular clusters. 47 Toucani, for instance, though it is near the small Magellanic Cloud, stands quite apart from it, isolated in a black sky.

We do not know the distances of any of these balls of stars. Those which have been examined spectroscopically shine like Canopus—that is, they are of a type intermediate between Sirius and our sun—but the chief light comes, of course, from the brighter stars, and it may be that the fainter stars mingled with them belong to a different type.

A remarkable fact lately discovered is that many globular clusters—but not all—contain a large number of variable stars. These vary in light in a period of about a day and have a range

of about one magnitude. They are not of the Algol type, nor quite of the usual "short-period" types, and it is not yet clear what is the cause of variation, though it seems probable that "cluster-variables" are double stars.

XIV

NEBULAE

Athwart the False Cross, from δ Velorum to ι Carinae, a line passing on leads to the round white spot which we found to be a star-cluster. A little further in the same direction is a larger curved white patch, bright enough to be visible, once it is familiar, even after the moon has risen. This is the Great Nebula in Argo, the Keyhole Nebula, in which Eta Argūs once blazed out. Even a binocular will divide it into two parts separated by a chasm, and will show the pearly background powdered over with many small stars.

But even the most powerful telescopes do not resolve this pale background into stars, as they resolve the star-cluster just mentioned: it remains a pearly mist, the brighter part strangely broken by dark rifts, the fainter, beyond the chasm, a tangled skein of long cloudy streaks reaching out into the darkness and gradually, irregularly, fading away.

When Herschel found this background unresolvable into stars, he concluded that it did not form part of the Milky Way, but was at an immeasurable distance behind, so that here he was looking right through the Galaxy at a still more distant region of stars, too distant and faint for his telescope to distinguish them separately. But the spectroscope has taught us that these cloud-like nebulae, though stars are often mingled with them, are not formed of stars at all, but of inchoate masses of faintly luminous gas; and they cluster so thickly in the Milky Way, generally avoiding other parts of the sky, that it seems evident that they lie in it and form part of it. They are also found in great numbers in the Greater Magellanic Cloud.

In the days of the Herschels photography had not come to the aid of astronomers, and Sir John speaks of the feeling of despair which often almost overcame him when trying, night after night, to draw the "endless details" of this nebula, so capricious in their forms are its curving branches and the dark spaces between, so strangely does its brightness vary in different regions, and so numerous are the stars scattered over it. With extraordinary patience he suc-

ceeded in cataloguing the positions of over 1200 of these. To compare the present aspect of the stars with his catalogue would be a laborious task, but might lead to results of great value.

The curious dark oval rift in the midst of the bright part, which he compared with a keyhole, he found to be not entirely devoid of light, a thin nebulous veil covering part of it; and many of the dark lanes and holes which in small instruments look perfectly black, are actually filled with faint stars and extremely faint nebulosity. The whole region near the nebula is exceedingly rich in stars, and also in star-clusters, as we have already seen. To quote Herschel once again:

"Nor is it easy for language to convey a full impression of the beauty and sublimity of the spectacle it offers when viewed in a sweep, ushered in as it is by so glorious and innumerable a procession of stars, to which it forms a sort of climax, justifying expressions which, though I find them written in my journal, in the excitement of the moment, would be thought extravagant if conveyed to these pages. In fact, it is impossible for anyone with the least spark of astronomical enthusiasm about him to pass soberly in review, with a powerful telescope and

in a fine night, that portion of the southern sky . . . such are the variety and interest of the objects he will encounter, and such the dazzling richness of the starry ground on which they are presented to his gaze."

In the constellation of the Sword-fish, on the edge of the Great Cloud of Magellan, is another nebula, 30 Doradūs, the Great Looped Nebula, which is even more marvellous in complexity of structure than the Keyhole Nebula in Argo. No photograph can reproduce, and no words can describe, the filmy appearance of these nebulae as seen in a telescope. The Looped Nebula seems to consist entirely of strangely curved and twisted streamers on a background of dark sky, with a few sparkling stars of various brightness scattered over it. At the complicated centre one of the loops forms a nearly perfect figure-of-eight, and another takes the outline of an eye.

Brightest of all the large gaseous nebulae is the well-known Orion Nebula, in the sword of the giant. A 3-inch telescope shows the main features well, the dark bay running into its brightest region, the row of three brilliant stars and the "trapezium" of four tiny ones very close

together, and the long outlying branches which have such fantastic curves. Because of its comparative brightness, its entrancing beauty, and its position where it can be seen from all latitudes, this nebula has been studied more than any other. The first drawing of it was made in 1656, the first photograph in 1880. It remains a baffling mystery still, but a few facts have emerged.

Its distance is immeasurable: it has been guessed at a thousand light-years. It must, therefore, be inconceivably vast in extent, but it is probably excessively tenuous, like a comet's tail, of which a million miles contain a negligible amount of matter. It is almost stationary in space, and a careful study of its form since 1758 proves that there has been no visible change, except perhaps in the relative brightness of some of its parts. Yet a recent spectroscopic investigation shows that movements are taking place in different directions within the nebula, and a slow rotation of the whole mass, or of its brightest portion, is suggested.

It is composed of faintly luminous gas, though whether it glows from heat or from some other cause we do not know. Photographs of nebulae

are very misleading with regard to brightness: one must remember that they have often been exposed for many hours. Helium, hydrogen, and an unknown gas which we call nebulium are mingled together, but not in equal quantities. In some of the fainter regions of the nebula, especially on the south and west borders, hydrogen produces a great deal of the light; in the brightest parts, near the trapezium, the glow of nebulium is much more prominent.

It is scarcely doubtful that many of the stars which appear to be involved in the nebula are physically connected with it, especially since they are of a type frequently found near nebulae, viz. very blue Orion-type stars with some of their hydrogen lines not dark but bright, as in the nebula.

The southern hemisphere is rich in nebulae smaller but of the same kind as these three magnificent objects, the Keyhole, the Looped, and the Orion Nebulae—that is, large irregular masses of gas, often spangled with stars—and each has some special beauty of its own; but for most of them large telescopes are needed to grasp the faint details. There is a nest of them in the northern part of Sagittarius: a cloudy

streak visible to the naked eye, a little north of the star γ Sagittarii, represents three nebulae and clusters close together—M 8, M 20, and M 21. The first is a wonderful combination of a bright scattered star-cluster and a gaseous nebula, with dark rifts dividing the cloudy structure. The second is the celebrated Trifid Nebula, less bright and large, but with even more striking black lanes which split the principal part into three almost separate portions. Many faint stars are scattered over it, but as they are scarcely more numerous than in the surrounding regions, most of them probably are not connected with the nebula. M 21 is a star-cluster.

Near these, where Sagittarius borders on Aquila,[1] is a small but very remarkable nebula, known from its shape as the Horseshoe or the Omega Nebula (M 17). It has a curious mottled appearance, with bright knots here and there.

And a little further west, near together, are two wonderful nebulae which surround the two stars Rho Ophiuchi and Nu Scorpii. Professor

[1] On Scutum in maps where this constellation is not included in Aquila.

Barnard, who has studied and taken exquisite photographs of many nebulae, considers the first of these the finest in the sky, because of its dark, winding lanes and the veiling of the stars in places by partly transparent nebulous matter.

XV

OTHER TYPES OF NEBULAE

The large irregular nebulae described in the last chapter are all more or less mingled with stars, at least in appearance, and it has been suggested that they are star-clusters in process of formation, with larger and brighter masses of filmy nebulosity all about them than at later stages, for long-exposure photographs reveal some exceedingly faint nebulosities surrounding Kappa Crucis and the Pleiades and other fully-developed star-clusters. But this can only be a guess until we know more about the nature of nebulae. In some regions of the sky we find vast spaces thinly veiled by nebulosity so faint and transparent that it seems to have reached the very limit at which matter can exist and be recognised as such. Thus in the constellation of Orion nearly all the bright stars are connected together by the vast convolutions of an exceedingly faint diffused nebula in spiral form, the innermost curve of which ends in the Great Nebula of the Sword,

and the whole region within is filled with faint light.

Quite distinct from these nebulae are others of perfectly regular form, very small, purely gaseous, without intermingling of any stars, but usually with one bright star-like nucleus at the centre. One form is the ring nebula, of which much the best known is that in the northern constellation of the Lyre. There are, however, some in the south. In a large telescope they appear like little golden wedding-rings against the dark sky background.

Another regular form is the "planetary nebula," so called because they look much like planets in large telescopes, being perfectly round or oval with a sharply-defined edge, and in several cases there are handle-like appendages, which may possibly be encircling rings, like the rings of Saturn. These nebulae shine with a peculiar bluish-green light, the colour of the unknown gas nebulium, of which they are chiefly composed. In Hydra, south of the star Mu, is one of the brightest and largest, known as H 27—that is, No. 27 on William Herschel's list. It is elliptical and of a lovely bluish colour, with a bright nucleus exactly in the centre.

By means of these sharply-defined central nuclei it has been found possible to measure

the approaching or receding movements of these nebulae, and although the one just mentioned is receding from us with a speed of only 3½ miles a second, their average speed is high, amounting to 40 or 50 miles a second. One in Sagittarius is receding at more than 80 miles a second, and another in Lupus attains a speed of over a hundred.

These are movements comparable with those of stars, but the average is higher than even for the most rapidly moving class of stars, the red-solar and Antarians. May we, then, place the planetary nebulae at the end of our star-series, since we saw that from the blue down to the red the average movements became faster and faster, and may we believe that all stars eventually become gaseous nebulae, as "new stars" seem to do? But we saw that in spectrum these nebulae rather resemble the stars at the other end of the series, the Wolf-Rayet, which lead directly to the hottest and brightest of all, the Orion stars. Planetary nebulae also resemble Wolf-Rayet, Orion, and Sirian stars, and differ from solar and red stars in that they cluster near the Milky Way, and are scarcely ever found far from it. Their place in the universe cannot be established yet.

One more kind of nebula, the most numerous

of all, remains to be mentioned, the so-called "white nebulae," which do not glow green like many of the brighter planetaries, but shine with a white light and have more or less star-like spectra, although not even the most powerful telescopes can resolve the white cloudiness into stars. The typical nebula of this class is the famous Andromeda Nebula, visible to the naked eye in northern skies as a large oval spot shining softly "like a candle shining through horn." Photography first disclosed the remarkable fact that it has the form of a great, closely-wound spiral, and further research has shown that by far the greater number of "white nebulae" have this form. There is a very fine one in Aquarius,[1] which has been known since 1824, but visual observations gave absolutely no idea of its true form. A photograph exposed for four hours in September 1912 showed it clearly as about two turns of a great spiral.

The distribution of this kind of nebula is quite different from that of the gaseous nebulae, for, instead of clustering towards the Milky Way, they avoid it, and especially the brightest region, where we saw that the others most abound, viz.

[1] N. G. C. 7293.

in Scorpio, Sagittarius, and Ophiuchus. On the contrary, the largest number of these is found near the north pole of the Galaxy—that is, as far removed from it as possible, in Virgo. There is, however, no corresponding group about the south pole of the Galaxy.

One investigator has found the distance of the Andromeda Nebula to be twenty light-years, but the distance and the movements of this type are difficult to discover. They are evidently very different from the others, and quite as mysterious.

XVI

THE CLOUDS OF MAGELLAN

One of the wonders which most attracted the attention of early explorers in the southern hemisphere, and roused as much interest as the Southern Cross, was the pair of faint clouds, looking like detached pieces of the Milky Way, which are seen in the neighbourhood of the South Pole. Marco Polo made a sketch of the Greater Cloud, which he describes wonderingly as "a star as big as a sack."

Although some star-maps show short branches of Milky Way pointing towards the two Clouds, this is incorrect, and they are quite separate from it. Herschel was struck by their isolation, especially in the case of the Little Cloud, which he described as situated in a "most oppressively desolate desert," its only neighbour being the globular cluster 47 Toucani, which is near, but separated by a perfectly black sky.

The Greater Cloud is much brighter to the

naked eye than the Lesser, and it is much more complex and interesting in the telescope. It contains, moreover, the wonderful Looped Nebula, of which we have already spoken.

Both Clouds consist of gaseous nebulae and star-clusters on a background of vague nebulosity and crowds of almost indistinguishable stars. But the white nebulae shun the Clouds, just as they shun the Milky Way.

An immense number of variable stars have been discovered in the Clouds of Magellan, of the same type as those in globular clusters. Miss Leavitt of Harvard Observatory catalogued from photographs no less than 969 in the Lesser Cloud and 800 in the Greater. In the latter the greatest number of variables was found in a stream of faint stars which connects a group of star-clusters with the Looped Nebula, and others occur locally in certain parts of the Cloud, but few are in its northern region or in parts where many of the brighter stars congregate. All the variables are very faint, the usual minimum in both Clouds being about fourteenth magnitude, and the maximum seldom more than one magnitude brighter. A few in the Lesser Cloud have been found with periods unusually long for this

"cluster type" of variables, amounting to 32, 66, and even 127 days. These longer periods seem to belong to somewhat brighter stars, but they are quite as exact as the usual period of a few days or a single day.

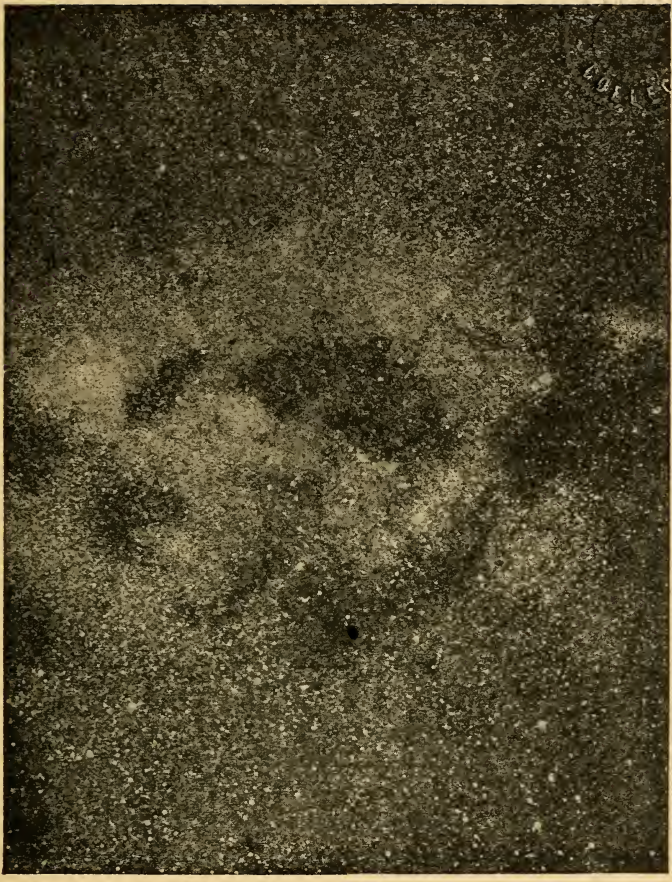
XVII

THE MILKY WAY

LIKE a great river returning into itself, the Galaxy encircles the starry heavens, and those who know only its northern course have no idea of its brilliance and wonderful complexity in its brightest part.

Its light is soft, milky, and almost uniform, between Cygnus and Sirius, but when it enters Argo it becomes extremely broad, and spreads out like a river on a flat marshy plain, in many twisting channels with spaces between. Where Canopus shines on the bank there is a narrow winding ford right across its whole breadth, as if a path had been made by the crossing of a star.

After this it suddenly becomes extremely narrow, but so bright that all the light which was shining in the broad channel seems to be condensed in this narrow bed. In the brightest, richest part the Great Nebula of Argo is easily distinguished by the naked eye. Contrasting



THE MILKY WAY IN SCORPIO, LUPUS, AND ARA
Photographed at Hanover, Cape Colony,
by Bailey and Schultz

with this and other bright condensations are black gaps, the largest and blackest of which is the well-known Coal-Sack near the Southern Cross.

The river now divides. One short stream, which goes north from Centaur towards Antares, is faint and soon lost; but another northern stream is so bright and so persistent that from Centaur to Cygnus we may say that the Galaxy flows in a double current. This northern portion forms first the smoke of the Altar on which the Centaur is about to offer the Beast, then passes through the Scorpion into the Serpent-Holder, and here, between η Ophiuchi and Corona Australis, the double stream has its greatest width. The northern division soon grows dim and seems to die out, but begins again near β Ophiuchi, and, curving through a little group of stars, passes through the head of the Eagle and forms an oval lagoon in the Swan.

The southern stream passes through the Scorpion's Tail into Sagittarius, then through the Eagle and the Arrow till it flows close beside the northern stream in the Swan, and finally rejoins it in a bright patch round α Cygni. Except just here it is much brighter than the northern

stream, and its structure is even fuller of wonderful detail than in Argo. In Sagittarius it consists of great rounded patches with dark spaces between. The brightest of these contains the star γ Sagittarii; then follows a remarkable region of small patches and streaks, the portion passing through Sagittarius and Aquila being thickly studded with nebulae. This is followed by another bright patch, rivalling that round γ Sagittarii, which involves the stars λ and 6 Aquilae.

This ends the most brilliant and wonderful part of the Milky Way. When well seen, as we see it in the south, it recalls Herschel's words, written at the Cape when it came into view in his telescope:

"The real Milky Way is just come on in great semi-nebulous masses, running into one another, heaps on heaps." And again: "The Milky Way is like sand, not strewed evenly as with a sieve, but as if flung down by handfuls, and both hands at once."

What is it? The ancients thought it the pathway of departed spirits, or fiery exhalations from the earth imprisoned in the skies, or a former road of the sun through the stars. But

Democritus and some other inquiring Greeks believed it to be the shining of multitudes of stars too faint and too close together to be seen separately, and we know this to be the truth. We know also, from simply counting the stars in different regions of the sky, that their numbers increase regularly as we go from north or south towards the Milky Way, and stars of all magnitudes are most abundant within its course. We saw also that star-clusters and certain kinds of nebulae frequent it, while other kinds avoid it, and that blue and white stars are the most abundant near it, and tend to move through space in planes parallel with it, while the redder stars are scattered and move about in all directions.

Facts like these lead astronomers to believe that the Milky Way has a definite relation with all the visible universe, that even the most distant nebula is not an outlying universe apart from ours, but all are parts of one vast stellar system.

It is possible that the Milky Way, which we see as a great circle, double in one part, is really an immense spiral, and that we are nearest one curve of it, the great southern division which

looks so bright. It may be that the spiral nebulae, vast though they are in terms of earthly measurement, are tiny models of one tremendous spiral which enfolds the universe with its coils.

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